# TIMELY INFORMATION

Agriculture & Natural Resources

# NET HOUSE VEGETABLE PRODUCTION: PEST MANAGEMENT SUCCESSES AND CHALLENGES

By Ayanava Majumdar* (Dr. A), Extension Entomologist & State Sustainable Agriculture Coordinator, Alabama Cooperative Extension System, Auburn University; and Mike Powell, American Farm Systems, Jemison, AL (a subsidiary of PolyProductos De Guatemala S.A., Guatemala)

**Contact information: 251-331-8416, bugdoctor@auburn.edu, 8300 State Hwy 104, Fairhope, AL 36532. Website: www.aces.edu/go/87. Facebook page: Alabama Vegetable IPM.*

Alabama is a significant producer of vegetables in the United States of America with over 50 different kinds grown under various environmental conditions. Tomato and bell pepper are some of the major vegetables produced by the state because of a high consumer demand for fresh produce giving good returns to the producers. However, the consistent consumer demand for unblemished produce also creates pressure on producers to use insecticides on a routine basis; such practices cause high environmental risk and unwanted human exposure to pesticides. Recent phase-out of several popular insecticides by the Environmental Protection Agency will create more pest management challenges for growers. The unusually high insect pest populations and activity levels seen in central and south Alabama (Majumdar, 2010) is a barrier to the vegetable production industry. Although many biological control methods are available, evaluation of the effectiveness of the insect exclusion techniques for sustainable vegetable production has been given limited attention in the U.S., except perhaps for the use of row covers. The physical exclusion of insect pests basically involves the separation of pest from host plants through some mechanical means. Some common examples of physical exclusion 'principle' in crop production include the use of row covers in squash to exclude vine borers, installing collars in soil around houseplants for stopping cutworms, bagging fruits in orchards to exclude fruit flies and many others. This article focuses on the effectiveness of large fixed-wall net house for insect pest management based on observations from a preliminary study of this new production system. This is the first intensive study of net house vegetable production system on large scale and trends reported herein need to be corroborated with further research.

**Background Information**

In many parts of the world, insect nets or screens are commonly used in crop production for reducing excessive solar radiation, weather effects on produce, or to keep away insects. Structures made from insect netting have different names, e.g., insect nethouse, net house, and net greenhouse, indicating a lack of standardization of this production system. Journal article search by this author provided some interesting articles on shade cloths (popular worldwide) and insect netting (popular in Africa) for fruit and vegetables, but few published articles described the effectiveness of large, more-complex net houses. Net houses and its variants have been used in some European, South American and Southeast Asian countries for producing egg plants (Kaur et al., 2004), leafy greens (Talekar et al., 2003) and cabbage (Martin et al., 2006). In Africa, mobile net houses made of mosquito nets (25-mesh) were effective as physical barrier against the diamondback moth, cutworms, and loopers providing 66 to 97% control of moths and caterpillars (Martin et al., 2006). Insect nets have also been integrated with hoophouses in Germany with limited success (e.g., Mutwiwa and Tantau, 2009). In China, Feng-cheng et al. (2010) demonstrated 90% reduction in the occurrence of tomato yellow leaf curl virus due to the near elimination of whiteflies under a 50-mesh net house. In the U.S., large-scale arched net houses have been constructed in California and Florida on 70+ acres for bell pepper, tomato, chili, and citrus production; however, very little scientific evaluation of the technology has been done and farmers have depended on vendor publications and experiences for adopting the technology (e.g., the website of Top Greenhouses Limited of Israel is a major manufacturer of net houses in the U.S. – for more information visit www.top.pro).

The objectives of this preliminary net house study were to: 1.) build the first vegetable net house unit in Alabama and understand some of the challenges to construction; 2.) document the level of reduction of insect pests and insecticide sprays under the net house versus open field vegetable production. Net house vegetable production system must be fine-tuned to the local climatic conditions before the technology can be adopted by growers; this study is the first step in that direction.

**Construction of a Net house**

Net house is a sealed structure made of synthetic fabric that is designed to keep insects away from host plants by physical exclusion. Net houses can be of variable height and width; some large net houses spread over hundreds of acres have been constructed in South American countries like Guatemala and Israel (http://www.amfarmsyst.com/photos/data/images/dsc01163.jpg). For this study, a large net house (150 ft x 46 ft) was constructed at the Allegri Farm in Fairhope (Baldwin County, Alabama). Construction began in April of 2010 and there were numerous challenges in establishing this first unit, including inclement weather. The insect netting was provided by American Farm Systems (Jemison, AL) – a subsidiary of PolyProductos De Guatemala S.A., Guatemala. A 50-mesh fabric was selected to exclude all small and big insects, per reports by Mutwiwa and Tantau (2009) and Fang-cheng (2010). The fabric can last 4-5 years under ideal conditions and is manufactured as long pieces that can be sewn together during construction. The fabric was stretched over wooden poles that were 17 ft tall in the center and 14 ft at the sides giving the net house a sloped roof to allow smooth wind flow over the large structure (Fig. 1). A network of cables ran between the wooden poles and the cables eventually anchored to the ground providing stability to the structure. The fabric was slowly pulled across the length of the structure to prevent air-traps underneath it that could destabilize the structure during construction. The two long side-walls of the net house were slanted to facilitate airflow around the unit (Fig. 2). The fabric in the side-walls was buried 2-3 feet into the ground so that the walls were taut. The fabric across the width was sealed later in order to allow land preparation, bedding and fumigation using conventional equipment (Fig. 3). Drip tape for irrigation also was installed during that operation. Note that the front and back sidewalls in a finished unit may be rolled up as needed to allow land preparation in early spring or winter. Once the field operations were over, the entire structure was sealed by burying the front and back fabric walls into the ground and a hinged double-door was constructed on the east face of the structure to allow entry of field personnel (Fig. 4). Due to the high value of tomato and bell peppers, those crops appear to be good candidates for net house vegetable production. The grower-cooperator manually transplanted three rows of bell peppers and tomatoes inside the sealed structure. The double-doors were kept locked as much as possible to limit traffic and the accidental introduction of insects.

**Insect Monitoring/Scouting Program**
Moth activity: In order to compare the activity of major insect pests (caterpillars) of vegetables inside and outside the net house, pheromone sticky wing traps (Fig. 5) were installed inside the structure and another set of traps was installed along a patch of untreated tomato plants outside the net house. Crops inside the structure were also directly scouted for insect damage. The insect pests monitored using traps included the tomato fruitworm, tobacco budworm, loopers (two species), fall armyworm, and beet armyworm. These pheromone traps contain a species-specific lure placed on a replaceable sticky bottom. Moth trap catches, observed every 10-12 days, provided evidence regarding pest pressures (i.e., pest activity and density) for that particular species. This insect monitoring program generated valuable information to quantify the effectiveness of insect netting under the naturally high insect pest pressures existing in south Alabama.

Caterpillar activity: In order to quantify the difference in pest pressures in net house plants versus open-field plants, sentinel (untreated) rows of tomatoes were maintained outside. Total number of caterpillars (primarily armyworms and hornworms) was counted in a cluster of 10 plants every 10 feet of row for a total of 40 plants (i.e., 4 replications). Since hornworms can completely defoliate a tomato plant early in the season, hornworms were removed after observations were completed. This helped in assessing mid-season armyworm pressure on the untreated crop.

**Results and Discussion**
In this study 'Celebrity' tomato and 'California Wonder' bell pepper (Fig. 6) were planted per industry recommendation. Although plant establishment and initial plant growth were very encouraging, the net house technology offered several challenges that growers must be aware of, for example:

1. Choosing what to plant: Growers must realize that net house technology is management intensive. Minimal data is available for producers regarding which vegetables and what varieties may be suited for net houses. It will probably take many years of research to accurately evaluate the suitability of various crops for commercial-scale net house production. While bell peppers and tomatoes grew well in this study, yields were affected by high stress levels due to delayed planting. The drought in 2010 aggravated pest problems resulting in insect and disease flare-ups. Note that this article is not providing any yield data since there were too many variables that affected project outcomes.
2. Managing the high heat and humidity levels: Due to the fine fabric, rain and heat got trapped under the structure in summer beyond June. Results from this study indicated that the lack of adequate ventilation due to the sealed 50-mesh fabric walls raised the temperatures as high as 138F (Table 1) which was stressful to the bell pepper and tomato varieties tested. Humidity levels reached 99% on most days which favored disease development and poor fruit set. In a hot dry year, net house vegetable production could be a challenge for producers but the technology may be more suitable for winter/early spring vegetable production (season extension). Growers can install fans at various heights inside the net house in order to facilitate aeration and drying up of soil. Raising the height of the structure is helpful in keeping the heat away from plants.
3. Shade cloth may be integrated within a net house: It is worth noting that a research done in Israel suggests that colored net houses may reduce temperature fluctuations and promote better physiological growth of plants (Shahak et al., 2004). In this study, a 50-mesh black shade cloth was installed under the white netting that significantly reduced heat levels inside the structure and promoted better plant health. This shade cloth is retractable for the entire length of the structure allowing better temperature regulation.
3. Weed management: The heat and humidity under a net house not only boosted the vegetative growth of the main crop but also enhance weed competition. Growers may face intense weed pressures within few weeks unless the planted area is kept weed-free through chemical or mechanical means. Cover crops may be used to suppress weed growth and conserve natural enemies under a long-standing unit.
4. Cost of net house technology: Due to several delays and errors in constructing this net house, it is difficult to provide a dollar figure at this point. Despite the lack of a cost-benefit analysis, it appears that cost of basic construction materials can be kept fairly low if local resources are utilized. The fabric can be bought in bulk at cheaper rates if a large structure

is desired by the farmer. In Vietnam, where labor and supplies are cheap, nongovernmental organizations have assisted construction of large net houses with less than $200 investment (Ecodana, 2011).

Insect pest control: Insect netting is very effective in reducing moths and caterpillars on high-value vegetables. Reduction in the number of insect pests is the overall goal of the net house technology and a 50-mesh white fabric worked very well to block a number of major vegetable insect pests from reaching the crops. Preliminary data based on pheromone trap catches (Table 2) indicated activity of moths inside net houses to be 82-100% lower than in open field. The first insect trap catches for beet armyworm and loopers were recorded in June of 2010. Interestingly, there was one outbreak of aphids under the net house which is consistent with observations from other studies (e.g., Talekar et al., 2003). Cotton aphid (*Aphis gossypii*) and potato aphid (*Macrosiphum euphorbiae*) were the predominant aphid species inside the net house. There were significant differences between the number of armyworms and hornworms recovered from the net house and outside (Table 3). Caterpillars were detected in low numbers inside the net house but heavy populations occurred outside (Table 3). One reason for armyworm outbreaks is that female moths deposited eggs on the netting (Fig. 7) and first instar caterpillars crawled across the minute opening near joints to infest the plants; Talekar et al. (2003) had similar experiences with net house vegetable production in Taiwan. It is suspected that aphids were introduced into the net house via infested transplants at the beginning of the season. Therefore, farmers using net house production system have to be vigilant and scout crops to detect accidental invasions in a timely manner. In this study, aphids on bell peppers were managed by a single spray of pymetrozine at the full recommended rate. Besides aphids, grasshopper that got trapped during the construction process along with weed pressure provided some challenge. However, grasshopper populations decreased as the season progressed and no insecticidal intervention was necessary. Only one brown stink bug specimen and zero leaffooted bugs were found during the entire season suggesting adequate exclusion of this important pest under a net house. Leaffooted bugs (*Leptoglossus* sp.) were as high as 2-4 per untreated tomato fruit and 6-14 per untreated eggplant fruit grown outside the net house (Fig. 8). Overall, a net house can provide major relief to vegetable producers from several insect pests and this technology could become highly attractive for organic farmers in future.

Crop harvest: Due to heat stress and other factors, yield from plants was not consistent with known production levels of the varieties (data excluded from this report). Delays in fungicide applications also increased fruit deterioration and fruit drop. Future studies will aim at controlling these variables and then compare yields in order to provide a reliable estimate of the cost effectiveness of net house vegetable production system.

**Future Directions for Net House Research**

It is evident that the net house vegetable production technology has numerous insect control advantages as well as disease control challenges that may be solved with continued research. Due to the high upfront cost of this technology, it is anticipated that organic and sustainable crop producers in high pest pressure areas of southeastern U.S. may be more willing to use the large net house after adjusting the technology to their situation. Further research is needed to screen heat-tolerant tomato, bell pepper, and other varieties that may be suitable for net house vegetable production. A trade-off can be expected between the use of a lighter fabric (i.e., 30- to 50-mesh with large holes to facilitate aeration) and insect control success, since small insects will be able to get through a lighter fabric. Talekar et al. (2003) suggested using no less than 30-mesh insect net for vegetable production in the tropics. Growers in parts of Alabama with moderate insect pressures may be able to use a fabric with <50 mesh depending on the target insect.

Reduction in moth and caterpillar numbers inside the net house ranged from 82 to 100% based on pheromone trap catches and direct crop scouting; thus, the effectiveness of physical exclusion of insect pests appears similar to many published accounts (Martin et al., 2006; Feng-cheng et al., 2010). The number of insecticidal sprays was reduced to one application of a selective insecticide, which is an encouraging trend. The occasional pest outbreaks observed inside the net house may have been initiated from insects emerging from the soil (e.g., grasshoppers), infested transplants (e.g., aphids), or small caterpillars crawling across the net (e.g., armyworms); these infestations were probably enhanced by the reduced action of natural enemies excluded by the sealed net house. Organic vegetable producers who may adopt a net house vegetable production system can use OMRI-approved insecticides for controlling pockets of insect outbreaks or use natural enemies sold commercial for inundative releases to control pests.

**References:**


1. Ecodana. 2011. Net greenhouses as substitute for chemical fertilizers and pesticides in Vietnam. [Online] http://ecodana.com/1891/net-houses-as-substitute-for-chemical-fertilizers-pesticides-in-vietnam/. Accessed on February 2, 2011.
2. Feng-cheng, X.U., L. Hui, L. Li-min, L.L. Fang-fang, C. Wen-hua, and L. Ding-peng. 2010. Initial report about prevention and controlling of tomato leaf curl virus with 50-mesh insect nets throughout the whole growing season. China Vegetables. 8: 61-64.
3. Kaur, S., S.S. Bal, G. Singh, A.S. Sindhu, and T.S. Dhillon. 2004. Management of brinjal shoot and fruit borer, Leucinodes orbonalis Guenee through net house cultivation. Acta Hort. 659: 345-350.
4. Kittas, C., N. Rigakis, N. Katsoulas, and T. Bartzanas. 2009. Influence of shading on microclimate, growth and productivity of tomatoes. Acta Hort. 807: 97-102.
5. Majumdar, A. 2010. Online Exclusive: Results from the 2009 Insect Monitoring Pilot Project in Alabama. American Vegetable Grower (R. Gordon, ed.). Miester Media, MI. [Online] http://www.growingproduce.com/americanvegetablegrower/?storyid=4204
6. Martin, T., F. Assogba-komlan, T. Houndete, J.M. Hougard, and F. Chandre. 2006. Efficacy of mosquito netting for sustainable small holder's cabbage production in Africa. Journal of Economic Entomology. 99: 450-454.
7. Shahak, Y., E.E. Gussakovsky, E. Gal, and R. Ganelevin. 2004. ColorNets: Crop protection and light quality manipulation in one technology. Acta Hort. 659: 143-151
8. Talekar, N.S., F.C. Su, and M.Y. Lin. 2003. How to grow safer leafy vegetables in net houses and net tunnels. International Cooperator's Guide, Asian Vegetable Research and Development Center. Publication #03-558.


**Table 1. Microclimate under a net house used for vegetable production in Baldwin County (Alabama) compared to the weather conditions outside. The year 2010 was hotter and dryer year compared to other years.**

| | MICROCLIMATE UNDER NET HOUSE | | CLIMATE OUTSIDE (AWIS*) | | |
|---|---|---|---|---|---|
| | Range of Temp. (F) | Range of Relative Humidity (%) | Average Temp. (F) | Average Relative Humidity (%) | Rainfall (inches) |
| Early May | NA | NA | 77 | 93 | 2.04 |
| Late May | 69-125 | 28-99 | 84 | 100 | 5.13 |
| Early June | 68-122 | 26-99 | 82 | 94 | 2.4 |
| Late June | 75-114 | 35-99 | 84 | 98 | 1.9 |
| Early July | 76-102 | 59-98 | 84 | 98 | 0.5 |
| Late July | 76-113 | 42-99 | 113 | 100 | 1.37 |
| Early August | 77-138 | 39-99 | 85 | 98 | 2.31 |
| Late August | 75-139 | 38-95 | 88 | 100 | 6.28 |
| Early September | NA | NA | 81 | 96 | 3.43 |
| Late September | NA | NA | 78 | 95 | 3.95 |

*Alabama Weather Information System

**Table 2. Reduction in moth numbers inside a net house recorded using sticky pheromone wing traps, Baldwin County, Alabama (2010).**

| | Tomato fruitworm (*Helicoverpa zea*)[a] | | Tobacco budworm (*Heliothis virescens*) | | Loopers[b] | | Beet armyworm (*Spodoptera exigua*) | | Fall armyworm (*S. frugiperda*) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Net house | Open field | Net house | Open field | Net house | Open field | Net house | Open field | Net house | Open field |
| May | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 8 | 0 | 13 |
| June | 0 | 1 | 0 | 2 | 0 | 17 | 0 | 23 | 0 | 15 |
| July | 0 | 2 | 1 | 23 | 0 | 27 | 0 | 40 | 2 | 11 |
| August | 0 | 7 | 0 | 10 | 0 | 23 | 0 | 69 | 4 | 11 |
| September | 0 | 8 | 0 | 5 | 0 | 37 | 0 | 75 | 5 | 14 |
| Mean (± SD) | 0 | 3.8 (± 3.4) | 0.2 (± 0.4) | 8.4 (± 8.8) | 0 | 20.8 (± 13.7) | 0 | 43 (± 28.9) | 2.2 (± 2.3) | 12.8 (± 1.8) |
| **% reduction** | **100%** | | **98%** | | **100%** | | **100%** | | **82%** | |
| ANOVA[c] | *F* = 6.171, *P* = 0.038* | | *F* = 4.338, *P* = 0.071 | | *F* = 11.494, *P* = 0.009** | | *F* = 11.092, *P* = 0.01* | | *F* = 66.681, *P* = 0.0001*** | |

Trap catches indicate population density and activity of moths over a time period.
[a]Insect numbers are cumulative for two observations each month.
[b]Includes soybean and cabbage loopers.
[c]Analysis of variance using SPSS Version 13.0.

**Table 3. Reduction in caterpillar numbers inside a net house compared to open-field vegetable production, Baldwin County, Alabama (2010)**

| | Armyworms[a] | | | Hornworm[b] | |
|---|---|---|---|---|---|
| | Net house | Untreated control (open field) | | Net house | Untreated control (open field) |
| Total caterpillar numbers (40 plants) | 7 | 32 | | 0 | 17 |
| Mean (± SD) | 0.1 (± 0.3) | 0.8 (± 0.8) | | 0 | 0.4 (± 0.6) |
| **% reduction** | **78%** | | | **100%** | |
| ANOVA[c] | F = 16.845, P = 0.0001** | | | F = 15.852, P = 0.0001** | |

[a]Includes the total number of beet (*Spodoptera exigua*), southern (*S. eridania*) and fall armyworms (*S. frugiperda*).
[b]*Manduca quinquemaculata*
[c]Analysis of variance using SPSS Version 13.0.

Fig. 1. Semi-completed structure of net house (50-mesh fabric) showing poles and sloping side walls. The center poles are 17 ft tall and the side poles are 14 ft tall. Location: Allegri Farm, Fairhope, AL.

Fig. 2. The long side-walls of this net house are buried 2-3 feet into the ground providing strength and stability to the structure. The short side-walls were left open for planting operations.

Fig. 3. A large net house allows mechanical planting and fumigation using conventional equipment. The front and back walls were sealed after land preparation but before transplanting vegetables.

Fig. 4. Construction of the double door and sealing of the net house. Vince Allegri (in picture) of Baldwin County became the first user of a net house for vegetable production in Alabama.

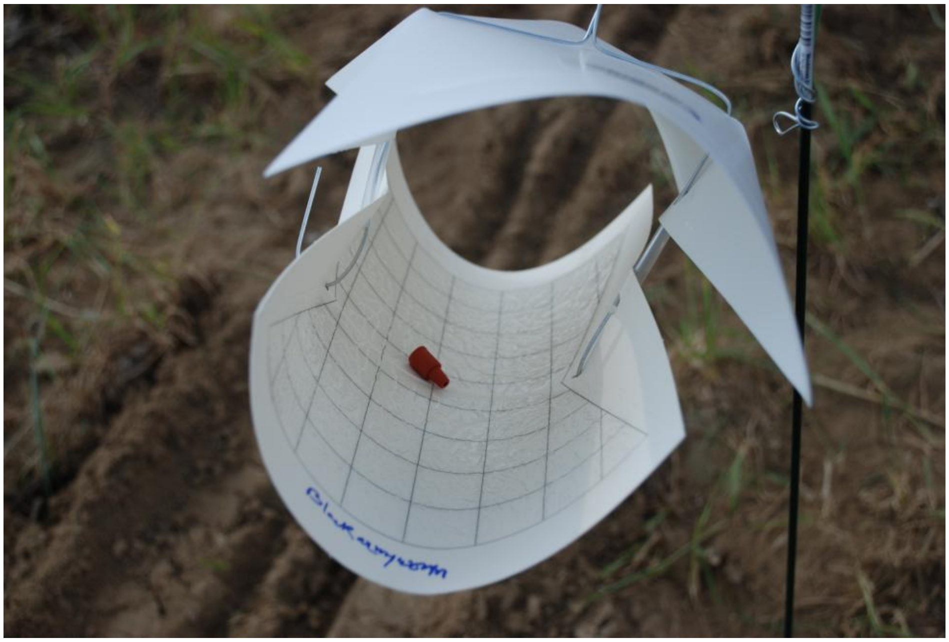

Fig. 5. Insect pheromone traps for monitoring insect pest activity throughout the season. Traps were installed inside and outside the net house to compare insect abundance and activity.

Fig. 6. Bell peppers grown inside a net house in Baldwin County, AL (2010)

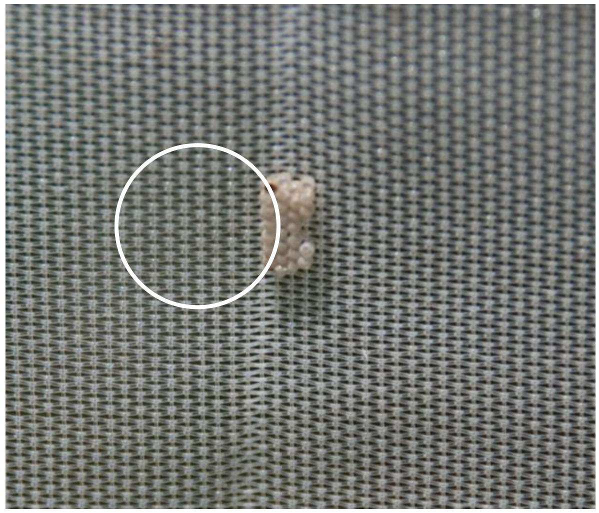

Fig. 7. Armyworm eggs deposited on the outside of a net house (50-mesh screen). Caterpillars can hatch on the net and crawl through the fabric or joints to reach host plants.

Fig. 8. Leaffooted bugs (3 species) were abundant in open-field tomato plants (sentinel plots), Baldwin County, AL.